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Research article

Use of Bio-activators in Goat Manure Fermentation and Effects of Solid Goat Manure-based Fertilizer on Growth and Yield of Sweet Corn

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Abstract

The presence of bio-activators in the decomposition of goat manure determines the nutrient content of the produced solid organic fertilizer. These experiments aimed to ascertain the impacts of several bio-activators on goat manured-based fertilizer's nutrient content and its effects on the growth and yield of sweet corn. The first experiment, arranged in complete randomized design with three replicates, employed five treatments of bio-activators. The treatments were (1) no bio-activator, (2) cow blood, (3) cow rumen+cow blood, (4) yeast+cow blood, (5) effective microorganism (EM4). The second experiment was a bi-factorial complete randomized block design with three replicates. The first factor was types of bio-activators: (1) no bio-activator, (2) cow blood, (3) cow rumen+cow blood, (4) yeast+cow blood, (5) effective microorganism (EM4), respectively. The second factor was dosage of goat manure-based solid organic fertilizers: (1) 5 Mg ha^{-1}, (2) 10 Mg ha^{-1}, (3) 15 Mg ha^{-1}. The results indicated that goat manure-based fertilizer produced using cow rumen+cow blood bio-activator had the highest nutrient content. The presence of bio-activators in goat manure-based fertilizer increased the weight of sweet corn (husked-ear and unhusked-ear), the length of sweet corn (husked-ear and unhusked-ear), and the weight of husked-ear sweet corn plot^{-1}, but not the sweet corn diameter (husked-ear and unhusked-ear), and sweetness level. Moreover, the use of goat manure-based fertilizer with 5 Mg ha^{-1} was generally sufficient to support growth and yield of sweet corn. The optimal combination of treatments to enhance sweet corn growth and yield was the interaction between the cow rumen+cow blood bio-activators and dosage of 5 Mg ha^{-1}.

Keywords: bio-activators; cow rumen; goat manure; organic fertilizer; sweet corn; vegetable production

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1. Introduction

Solid organic fertilizer is the major nutrient source for plant growth and development in organic agriculture production since it benefits crop production by maintaining positive effects on soil physiochemical and biological properties, which eventually leads to increased crop growth, yield and nutritional properties (Piya et al., 2018). According to Assefa and Tadesse (2019), organic fertilizer refers to fertilizer created by breaking down biodegradable organic materials into simpler, soluble molecules that are then further available for plant roots. In addition, examples of organic materials include manures, slurries, worm castings, peat, seaweed, sewage, guano, green mass compost, blood meal, bone meal, or seaweed extracts. Animal manure is one of the commonest organic fertilizers applied by farmers in many vegetable production areas, including the use of goat-manure based fertilizer (Ernawati et al., 2015).

The uses of goat manure-based fertilizer in vegetable production were found to increase the growth and yield of tomato (Purnomo et al., 2022), maize (Hariadi et al., 2016), sweetcorn (Uwah & Eyo, 2014) and soybean (Fitriani et al., 2023). Previously, Awodun et al. (2007) concluded that goat manure-based fertilizer was an excellent source of nutrients (N, P, K, Ca, Mg, and organic matter) for pepper growth and development. According to Hartatik and Widowati (2006), fresh goat manure contained 1.41% N, 0.54% P, 0.75 % K and 46.51% organic-C. Nevertheless, the nutrient properties of goat manure-based fertilizer are determined by its decomposition rate. Furthermore, goat manure has a grain-like texture with a C/N value generally above 30, which requires longer time to get physically decomposed as an organic fertilizer. The slow decomposition rate of goat manure must be overcome by deploying bio-activators to stimulate the decomposition process. Posavac et al. (2010) asserted that bio-activators are not fertilizers, but rather materials that contain beneficial microorganisms that actively break down and ferment organic waste from livestock waste, prevent the growth of pests and diseases, boost the photosynthetic capacity in plants, elevate fertilizer absorption, and enhance the quality of vegetative and generative growth in plants.

The rumen of ruminant animals including cattle, buffalo, goats, and sheep, is a natural material that can be used as a bio-activator since it contains xylanotic bacteria that are able to generate cellulose enzymes capable of speeding up the degradation of cellulose (Bhat & Bhat, 1997). In addition, the blood of ruminant animals generated in slaughterhouses is another waste for producing organic fertilizers (Ernawati et al., 2015) since this waste contains 4.94%, 0.16% and 0.93% of N, P and K, respectively (Roy et al., 2013). The presence of bio-activators in production of organic fertilizer determined the quantity and quality of nutrients in the solid organic fertilizers. It has been reported that application of bio-activators on soybeans increased plant growth and yield. Recently, Safitri et al. (2021) reported that the addition of various bio-activators in the production of goat manure-based organic fertilizer was able to provide the needs of N, P, and K for soybean growth. Clearly, the use of bio-activators in the decomposition of goat manure determines the nutrient content of goat manure-based solid fertilizer. Nevertheless, there has been less study of the effects of various bio-activators on nutrient properties of goat manure-based fertilizer and its effects on organically grown sweet corn. These experiments aimed to ascertain the impact of several bio-activators on goat manured-based fertilizer nutrient content and its effects on growth and yield of sweet corn.

2. Materials and Methods

2.1 Experiment I

The objective of this experiment was to determine the effect of several bio-activators on the nutrient properties of goat manure-based fertilizer. The experiment was conducted in the Composting House of University Bengkulu, Indonesia and laid out in complete randomized design with three replicates. There were 5 bio-activators which served as a single treatment, i.e*.,* (1) no bio-activator, (2) cow blood, (3) cow rumen+cow blood, (4) yeast+cow blood, and (5) effective microorganism (EM4). For the composition for each treatment, the amount of goat manure was 20 kg, cow blood was 3 L, cow rumen was 3 L, EM4 was 5 L of diluted 0.4% EM4 and granulated sugars was 500 g.

Each treatment was incubated for four weeks in a green plastic bucket (75 L in volume) and placed under a closed plastic tarpaulin to avoid rain. In addition, each of the mixtures was manually stirred and the cover was closed as necessary. After the incubation was completed, each of the goat manure-based fertilizers was sampled for nutrient content analysis. After two days of air drying, the samples were grounded, sieved through a 0.5 mm screen, and their pH, color, and N, P, K, and C contents were determined. The Kjeldahl method was employed to ascertain organic N, the Bray I method for determination of organic P, the Flame-photometer method to determine the organic K after soil extraction with 1N NH4 acetate, the Walky and Black method to analyze the organic C, and the pH meter to determine the pH (Prasetyo et al., 2009).

After doing a statistical analysis of the data using analysis of variance at $P<0.05$, Significant differences among various treatment means were examined using Duncan's Multiple Range Test at $P<0.05$.

2.2 Experiment II

This experiment aimed to ascertain the effect of various goat manure-based fertilizers on sweet corn growth, yield and nutrient uptakes. This study was conducted on Inceptisols from September to December 2022, settled in bi-factorial complete randomized block design with three replicates. The first factor was the types of bio-activators used in the production of goat manure-based solid organic fertilizer produced in experiment I, i.e*.,* (1) no bio-activator, (2) cow blood, (3) cow rumen+cow blood, (4) yeast+cow blood, and (5) effective microorganism (EM4). The second factor was the dosage of goat manure-based solid organic fertilizer, i.e., (1) 5 Mg ha^{-1}, (2) 10 Mg ha^{-1}, and (3) 15 Mg ha^{-1}.

The experimental site was cleaned, harrowed and 9 soil beds of 5 m x 1 m in each block were constructed two weeks before planting. Each bed in the blocks was separated by 0.5 m and the blocks were separated 1 m away and vermicomposted with 15 Mg ha^{-1}. Two sweet-corn seeds (*cv.* Paragon) were planted in each planting hole at a spacing of 0.7 m x 0.25, and the worse seedling was removed at one week after planting to make 20 plants in each plot. Composited soil samples (from 0.2 m depth) of the experimental site were analyzed using Khejdhal, Bray I, Flamephotometric, Walkey and Black, and electrometric procedures were used to analyse the nutrients for N-total, available P, exchangeable K, and pH, respectively (Prasetyo et al., 2009). Nutrient content analyses revealed that the soil pH at this site was 4.2 and its N, P, K and organic C contents were 0.21%, 7.47 ppm, 0.23 me/100 g, and 1.13%, respectively. In addition, the experimental soil had a sand fraction of 30.27%, clay 42.85% and dust 26.87%.

All sweet corn plants were manually irrigated every other two days, unless precipitation occurred, until the soil reached field capacity. Weeds appeared in the experimental plot were manually controlled at two-week interval throughout the planting time. At the time of weeding, the soil around the sweet corn's stem was raised up to make sure that the plant stood well and prevent up-rooting. Application of a 5 mL L^{-1} concentration of the biopesticide PHEFOC®, which contains diallyl sulfide, diallyl disulfide, diallyl trisulfide, allyl methyl disulfide, allyl methyl trisulfide, azadirachtin, tithonia leaves, soursop leaves, tobacco leaves, garlic, and lemongrass, to every plant in the experimental plots was conducted on September 20th and October 9th, 2022.

Harvesting of sweet corns was conducted at 65 days after planting. The effects of the treatments on sweet corns were determined (5 plant samples plot^{-1}) in terms of plant height at 42 days after planting (cm), leaf number at 42 days after planting, stem diameter at 42 days after planting (mm), total chlorophylls (mg g^{-1} fresh weight), leaf greenness at 42 days after planting (SPAD index), kernel sweetness (brix), and nutrient (N, P, K) uptake were determined by taking leaf samples from fully developed leaf above the sweet corn ear and calculated as = SNC/100 SDW (Ardakani et al., 2011), where SDW is shoot dry weight (g) and SNC is selected nutrient content in plant (g plant^{-1}). Stem diameter was measured at the time of flowering at the first node using a caliper (mm).

Meteorology, Climatology, and Geophysical Agency Bengkulu provided the meteorological data for the experiment, which included monthly rainfall, relative humidity, and air temperatures (ID WMO: 96255). Before doing an analysis of variance, the data were evaluated through a homogeneity test using the Statistical Analysis System ($P<0.05$). Duncan's Multiple Range Test was deployed to compare mean treatment effects ($P<0.05$).

3. Results and Discussion

3.1 Nutrient properties of goat manure-based compost

During the fermentation of goat manures, the daily relative humidity in the composting house ranged from 77% to 95% (average of 86%), and the air temperatures ranged from 24ºC to 28.10ºC (average of 26.05ºC). The application of the bio-activator (bloods, rumen, or their combinations) in the production of the goat manure-based solid fertilizers had significant effects on N, Ca and Mg, but not on pH, P, K, C and C/N value.

The insignificant effects of the bio-activators on the pH, P, K, C and C/N ratio of goat manure-based compost were presumably brought about by complex factors affecting the functions of microorganisms in decomposing the goat manure. The results revealed that the use of different combinations of bio-activators had similar effects on the pH of goat manure-based composts (ranged from 7.12 to 7.31). Although the treatments had similar effect on pH, the values remained within the acceptable range (4.0-9.0) specified in the Minimum Technical Specification Standard for solid organic fertilizers issued by the Ministry of Agriculture of the Republic of Indonesia (2019). It is common that well-decomposed organic fertilizers have pH around the neutral point. Previous research found that pH of goat compost was 7.8 (Irshad et al., 2013). In addition, the treatments also had no effects on C/N values of the goat manure-based fertilizer, which ranged from 6.20 to 8.45. These values were well below the Indonesian standard of less than 25. Similarly, the P, K, and C contents of the goat manured-based were very much lower than Indonesian standard for solid organic fertilizer, i.e., $P_2 0_5$, K_2O, and C contents must be at least 2%, 2%, and 15 %, respectively. The selected nutrient properties of goat manure-based fertilizer as affected by various bio-activators are presented in Figure 1.

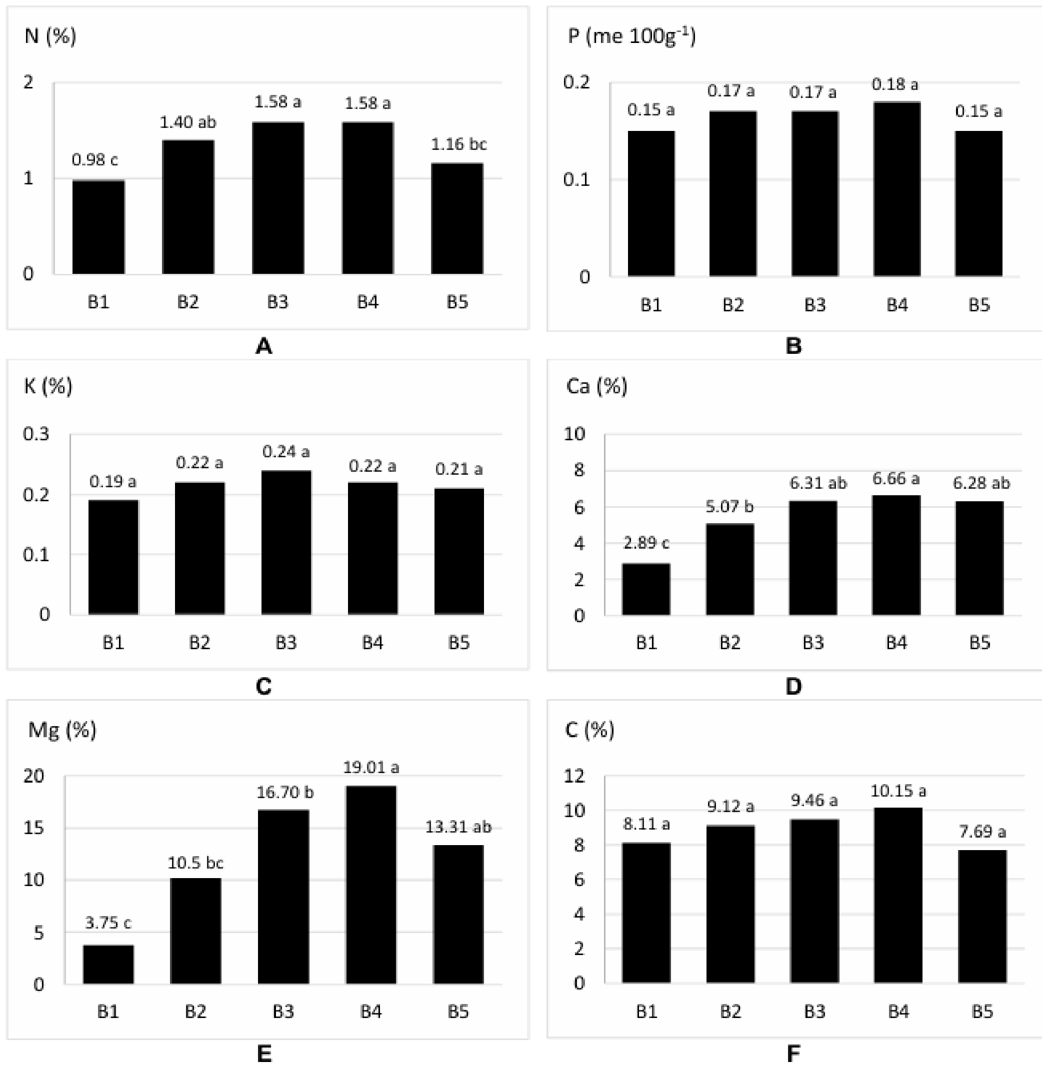

Figure 1. Effects of bio-activators on nitrogen (A), phosphorus (B), potassium (C), magnesium (D), calcium (E), and organic carbon (F) contents of goat manure-based fertilizer (means followed by the same letter in each graph are not significantly different according to Duncan's Multiple Range Test (P≤0.05). B1, B2, B3, B4, and B5 represent treatments of no bio-activator, cow blood, cow rumen+cow blood, yeast+cow blood, effective microorganisms (EM4), respectively).

These low P, K, and C contents as well as the low C/N values might be due to microorganisms excessively consuming nutrients from the decomposed organic materials as energy sources during the decomposition of goat manure. The presence of *Lactobacillus* sp., *Bacillus* sp., *Acinetobacter* sp., *Pseudomonas* sp. and *Celullomonas* sp. bacteria in cow rumen or blood (Lamid et al., 2006), which are xylanolytic bacteria, may have accelerated the decomposition process as they are considered fast-growing and metabolically active in the early stages of organic matter decomposition. Since goat manure-based fertilizer in this work was decomposed for four weeks, it could be explained why P, K, and C contents of goat manured-based were very much lower than Indonesian standard for solid organic fertilizer. It is, therefore, suggested that the decomposition of goat manure using cow blood or cow rumen bioactivators should be limited to less than four weeks to prevent excessive microbial activity. Research by Trivana and Pradhana (2017) also found that the speed of organic matter decomposition, including goat manure, depended on the type of bioactivator used. Their study concluded that certain bioactivators significantly shortened the decomposition time to less than 20 days while still achieving nutrient content that met the Indonesian National Standard (SNI:19-7030-2004). Similar results were also reported by Pancapalaga et al. (2021), where the addition of cow rumen as a bioactivator in the 20-day decomposition of goat manure produced nutrient contents in the resulting fertilizer that complied with national standards.

The presence of cow blood and cow rumen (treatments B2, B3, and B4) increased N, Ca, and Mg contents of the goat manure compost-based (Figure 1). Increased N was related to the roles of microorganisms in the decomposition of goat manure that produced ammonia and nitrogen (Cesaria et al., 2014). Recently, Pratiwi et al. (2023) suggested that the breaking down of organic matter by bacteria from ammonia into nitrites increased the overall N-content and raised nitrogen levels. In addition, the increase in calcium and magnesium contents in the goat manure-based fertilizer was probably related to its high pH, which further increased the availability of calcium and magnesium. According to Abbott et al. (2018), manure-modified soils typically have higher pH values that might increase the availability of calcium and magnesium for plants. The magnesium contents in treatments B3, B4 and B5 were higher than those in treatments B1 and B2. However, N levels were less than minimum requirement issued by Indonesian Ministry of Agriculture, i.e. a minimum of 2% (Minister of Agriculture of the Republic of Indonesia, 2019). These results imply that duration of incubation should be less than four weeks when rumen or blood is employed as the bio-activators. Further research should focus on shortening the decomposition period of goat manure using rumen or blood-based bio-activators to avoid nutrient loss and reduction of C/N ratio.

3.2 Sweet corn responses

The results of various types of goat manure-based fertilizer from experiment I were used in the second experiment. The effects of various types of bio-activators and dosages of goat manure-based organic fertilizer on sweet corn growth and yields are summarized in Table 1.

The results from this experiment showed that type of goat manure-based fertilizer significantly affected the plant height, leaf number, stem diameter, shoot fresh-weight, shoot dry-weight, and N, P, K uptakes of sweet corn. Meanwhile, the dosage of goat manure-based fertilizer significantly affected plant height, leaf number and K uptake of sweet corn. The interaction of type and dosage of goat manure-based solid organic fertilizer significantly influenced leaf greenness of sweet corn. In addition, type of goat manure-based significantly affected the weight husked-ear, weight of unhusked-ear, length of husked-ear, length of unhusked-ear, and weight of husked-ear plot^{-1} of sweet corns, but not on the diameter of husked-ear, diameter of unhusked-ear, and sweetness level of sweet corn. Meanwhile, the dosage of goat manure-based significantly affected the weight of husked-ear, weight of husked-ear plot^{-1} and the sweetness level, but not the weight of unhusked-ear, length of husked-ear, length of unhusked-ear, and the diameter of husked-ear, diameter of unhusked-ear of the sweet corn.

Table 1. Analysis of variance for the effects of various types of bio-activators and dosages of goat manure-based fertilizer on the growth and yields of sweet corn

Observed Variables	F-*values*		
	Types of Bio-activators (T)[a]	Dosages of Goat Manure-based (D)	Interaction (TxD)
Plant height	9.80**	4.33*	1.82ns
Stem diameter	14.27**	0.97ns	1.02ns
Leaf number	5.98**	7.43**	0.54ns
Leaf greenness	7.83**	1.32ns	2.63*
Chlorophyl content	2.47ns	0.39ns	1.90ns
Shoot fresh weight	9.55**	0.02ns	0.92ns
Shoot dry weight	9.49**	2.94ns	1.37ns
N uptake	11.47**	1.77ns	1.05ns
P uptake	7.21**	1.09 ns	2.42ns
K uptake	4.54**	3.80*	2.10ns
Weight husked ear	8.77**	4.47*	3.57**
Weight of unhusked ear	6.13**	2.74ns	3.40**
Length of husked ear	3.07*	2.72 ns	1.41 ns
Length of unhusked ear	3.21*	0.18 ns	0.50 ns
Diameter of husked ear	2.38ns	0.39 ns	0.99 ns
Diameter of unhusked ear	1.17ns	0.10 ns	0.83 ns
Weight of husked ear plot^{-1}	16.95**	9.40**	5.30**
Sweetness level (Brix)	2.64ns	8.23**	1.38 ns

Notes: ns, *, **= insignificant, significant at F=0.05, significant at F=0.01, respectively. [a]The bioactivator treatments included (1) no bio-activator, (2) cow blood, (3) cow rumen+cow blood, (4) yeast+cow blood, (5) effective microorganisms (EM4), respectively.

3.2.1 Effect of goat manure-based types on sweet corn growth and yields

It appeared that the presence of cow blood and cow rumen generally increased the plant height, leaf number, stem diameter, shoot fresh-weight, shoot dry-weight, and N, P, K uptake of sweet corn (Table 2). These responses might have resulted from the nutrient content in the goat manure-based fertilizer that contained cow rumen+blood bio-activator having the highest nitrogen content compared to other goat manure-based fertilizers (Figure 1). In addition, the high nitrogen uptake that resulted from goat manure-based contained cow rumen+blood bio-activator could increase sweet corn growth. According to Nugroho (2015), the presence of nitrogen in the rhizosphere increased the growth of stems and leaf greenness which eventually maximized the photosynthesis process and fostering plant growth. Nitrogen is very essential for the synthesis of protein and amino acids in plants, as well as for supporting plant metabolism and vegetative growth (Kirkby, 2023).

Table 2. Effects of various types of bio-activators in goat manure-based fertilizer on sweet corn growth

Observed Variables*	Types of Bio-activators in Goat Manure-based				
	No bio-activator	**Cow Blood**	**Cow Rumen + Cow Blood**	**Yeast + Cow Blood**	**Effective Micro-organism (EM4)**
Plant height (cm)	155.55[b]	168.33[a]	172.77[a]	172.33[a]	152.22[b]
Stem diameter (mm)	19.76[b]	21.76[a]	22.02[a]	21.08[a]	18.38[c]
Leaf number	10.11[bc]	11.33[a]	11.22[a]	10.88[ab]	9.44[c]
Leaf greenness (SPAD index)	38.84[b]	38.30[b]	40.45[a]	40.47[a]	37.64 [b]
Chlorophyl content (mg/g)	0.49[ab]	0.55[a]	0.48[ab]	0.39[b]	0.40[b]
Shoot fresh weight (g)	272.78[b]	399.43[a]	426.22[a]	395.97[a]	234.11[b]
Shoot dry weight (g)	100.25[c]	113.25[b]	134.56[a]	118.65[b]	109.30[bc]
N uptake (%)	0.04[b]	0.06[b]	0.26[a]	0.25[a]	0.10[b]
P uptake (%)	0.05[b]	0.06[a]	0.06[a]	0.06[a]	0.05[b]
K uptake (%)	0.02[b]	0.05[a]	0.05[a]	0.05[a]	0.01[b]

* Duncan's multiple range test (P≤0.05) indicates that there is no significant difference between the means in the same row that are followed by the same letter.

Strong vegetative growth can also be reflected by stem diameter of sweet corn. This study revealed that the goat manure-based fertilizer contained cow rumen+blood bio-activator and had the highest nitrogen uptake also produced the best stem diameter. Sweet corn required a large quantity of nitrogen to have robust stem development. Pangaribuan et al. (2017) concluded that high nitrogen uptake by sweet corn brought about an increase in stem diameter.

Shoot dry weight is another reliable growth variable to measure crop responses to specific treatments. In this study, the highest shoot dry-weight of sweet corn was recorded in plants fertilized with goat manure-based fertilizer that contained cow rumen+blood bio-activator. According to Jiaying et al. (2022), plant dry weight is the result of the nutrient absorptions such as nitrogen, potassium and phosphorus which are further used by plants to construct plant tissues. Indeed, plant dry weight is a reflection of increased nitrogen uptake in sweet corn. High plant dry weight could have resulted from the effect of goat manure-based fertilizer on soil physical properties, including soil aggregate. According to Ros et al. (2006), organic materials contained in manure-based fertilizer increased soil granulation and aggregate, which later improve soil water holding capacity and permeability. In addition, the amendment of organic matter into the soil increases the biological properties of the soil. The results from this experiment also indicated that there was increased leaf greenness of sweet corn, especially in corn fertilized with cow rumen+blood bio-activator. Such an increase might have been due to nitrogen effects on chlorophyll formation (Kirkby, 2023). Putra & Ningsi (2019) concluded that increased soil nitrogen elevated the formation of chlorophyll in the leaves of *Pennisetum purpureum* cv mott. In addition, this study suggested that nitrogen uptake by sweet corn was higher than uptake of phosphorus and potassium. This was presumably due to higher nitrogen levels in goat manure-based fertilizer than those of phosphorus and potassium (Figure 1). This was in accordance with Fajarditta et al. (2012), who concluded that nutrient content in plants was influenced by nutrient concentration in the soil.

The presence of bio-activators (cow blood, cow rumen, yeast, and EM-4) generally increased the weight husked-ear, weight of unhusked-ear, length of husked-ear, length of unhusked-ear, and weight of husked ear plot^{-1} of sweet corn, but not the diameter of husked-ear, diameter of unhusked-ear, and sweetness level of sweet corn (Table 3).

The superiority of the goat manure-based fertilizer that contained bio-activators (cow blood, cow rumen, yeast, and EM-4) in promoting yields of sweet corn might have been due to the high N, Ca, and Mg content in the goat-based manure fertilizer (Figure 1). These nutrients played important roles in photosynthesis, which eventually increased the weight husked-ear, weight of unhusked-ear, length of husked-ear, length of unhusked-ear, and weight of husked-ear plot^{-1} of sweet corn. According to Nugroho (2015), increases in sweet corn ear weight occurred in proportion to the photosynthesis rates and the rate of translocation of photosynthesis to the sweet corn as well as increases in seed fillings and ear enlargement ear. Similarly, Fitriani et al. (2023) concluded that the addition of cow rumen in combination with blood bio-activators produced higher soybean yield compared to that of soybean grown using synthetic fertilizers. In addition, C/N ratios of goat-based manure fertilizer ranged from 6.20 to 8.45, indicating a well-done decomposition process of organic fertilizer and eased the nutrient absorption, especially the potassium element which functions in the formation of ear and seed of sweet corn. Lukiwati & Pujaningsih (2014) corroborated this discovery by concluding that the addition of organic materials was able to produce an ideal growing environment for sweet corn by increasing the nutrient obtainability, particularly potassium.

Table 3. Effects of various types of bio-activators in goat manure-based fertilizer on sweet corn yields

Observed Variables*	**Types of Bio-Activators in Goat Manured-based**				
	No Bio-activator	**Cow Blood**	**Cow Rumen + Cow Blood**	**Yeast + Cow Blood**	**Effective Micro-organism (EM4)**
Weight husked ear (g)	288.52^{b}	290.28^{b}	351.16^{a}	336.85^{a}	282.51^{b}
Weight of unhusked ear (g)	185.21^{a}	201.66^{a}	197.14^{a}	206.72^{a}	143.08^{b}
Length of husked ear (cm)	20.33^{ab}	22.11^{a}	22.11^{a}	21.66^{ab}	20.00^{b}
Length of unhusked ear (cm)	15.11^{b}	17.55^{a}	17.88^{a}	18.11^{a}	16.44^{ab}
Diameter of husked ear (cm)	50.61^{a}	52.98^{a}	53.07^{a}	53.97^{a}	47.91^{a}
Diameter of unhusked ear (cm)	43.33^{a}	45.01^{a}	45.87^{a}	45.90^{a}	42.12^{a}
Weight of husked ear plot^{-1} (kg)	5.44^{b}	5.80^{b}	7.01^{a}	6.74^{a}	5.65^{b}
Sweetness level (Brix)	11.55^{a}	12.22^{a}	13.11^{a}	12.55^{a}	12.22^{a}

*Duncan's multiple range test ($P \leq 0.05$) indicates that there is no significant difference between the means in the same row that are followed by the same letter.

Surprisingly, the application of certain bio-activators clearly improved NPK uptake which was not followed by significant enhancement in the sweetness levels of sweet corn (Table 3). It is clear that improved NPK uptake does not always translate into higher Brix levels in sweet corn. This disconnect can indeed be influenced by several environmental and physiological factors, including water availability. Sufficient water must be supplied to sweet corn during grain filling is critical for sugar translocation and accumulation in kernels. During the study period, the rainfalls in September, October, and November 2022 were 342 mm, 470 mm, and 268 mm, respectively. An ideal monthly rainfall for sweet corn growth and development is around 110-170 mm per month with even distribution (Neild & Newman, 2025). Excessive water during the grain filling might explain why the sweetness level of sweet corn in this experiment was less affected by the treatments. Excessive water during grain filling might have reduced the sweetness level of sweet corn because it caused lower sugar translocation and accumulation into the kernel.

3.2.2 Effect of goat manure-based dosage on sweet corn growth and yield

Higher dosage application of goat manure-based organic fertilizer increased the leaf greenness of sweet corn but reduced plant height, shoot dry-weight and K uptake (Table 4). Similar trends were also observed for the effects of goat manure-based fertilizer on yields of sweet corn. However, the weight of husked-ear plant^{-1} and weight of husked-ear plot^{-1} were the best for sweet corn that had been fertilized with 10 Mg ha^{-1} of goat manure-based fertilizer (Table 5).

The results of this experiment suggest that the use of 5 Mg ha^{-1} of goat manure-based fertilizer was generally as effective as the use of 10 and 15 Mg ha^{-1} in influencing the growth of sweet corn. The application of solid organic fertilizer provided a buffer for the chemical, physical, and biological properties of the soil, and increased fertilization efficiency and land productivity (Supartha et al., 2012). According to Piya et al. (2018), the physio-chemical (aggregation, stability, pH, electrical conductivity, water holding capacity, bulk density, organic matter, and nutrients), biological (microbial population, enzymes), and soil structural stability qualities were all enhanced by the amendment of solid organic fertilizer. These changes might have supported the root and plant growth that eventually increased sweet corn yield. According to Hartatik et al. (2015), well-developed plant roots can more readily take water and nutrients from the soil, allowing for optimal plant growth and development to obtain maximum results. Pangaribuan et al. (2017) suggested that plant dry weight is associated with increased nitrogen uptake in sweet corn. Recently, Lubis et al. (2025) concluded that amendment with goat manure-based fertilizer increased sweet corn growth and yield.

3.2.3 Interaction effects

There was an interaction effect between the type and dose of goat manure-based fertilizer on the level of leaf greenness at 42 days after planting (Figure 2A). The best combination was yeast+cow blood bio-activators with a dose of 5 Mg ha^{-1}. Increased leaf greenness was probably due to the high N and Mg content in those goat-based manure fertilizers (Figure 1), which might have promoted the chlorophyll formation in sweet corn. According to Kirkby (2023), both N and Mg play important roles in the synthesis of plant chlorophyll. This study also revealed that there was an interaction effect between the type and dose of solid organic goat manure fertilizer on the weight of husked-ears of sweet corn (Figure 2B). In addition, there was an interaction between the type of bio-activator and dose of goat manure-based fertilizer on the weight of unhusked-ears of sweet corn (Figure 2C) and unhusked-ears of sweet corn plot^{-1} (Figure 2D).

Table 4. Effects of dosage of goat manure-based fertilizer on sweet corn growth

Observed Variables*	Dosages (Mg ha^{-1})		
	5	10	15
Plant height (cm)	168.60^{a}	165.33^{ab}	158.80^{b}
Stem diameter (mm)	20.28^{a}	20.63^{a}	20.90^{a}
Leaf number	10.60^{a}	10.60^{a}	10.60^{a}
Leaf greenness (SPAD index)	38.84^{b}	38.30^{b}	40.45^{a}
Chlorophyl content (mg/g)	0.49^{a}	0.46^{a}	0.45^{a}
Shoot fresh weight (g)	342.14^{a}	349.16^{a}	345.80^{a}
Shoot dry weight (g)	114.51^{ab}	121.01^{a}	110.09^{b}
N uptake (%)	0.11^{a}	0.17^{a}	0.14^{a}
P uptake (%)	0.05^{a}	0.06^{a}	0.05^{a}
K uptake (%)	0.03^{b}	0.04^{a}	0.03^{b}

* Duncan's multiple range test (P≤0.05) indicates that there is no significant difference between the means in the same row that are followed by the same letter.

Table 5. Effects of dosage of goat manure-based fertilizer on sweet corn yields

Observed Variables*	Dosages (Mg ha^{-1})		
	5	10	15
Weight husked ear (g)	289.62^{b}	320.16^{a}	319.82^{a}
Weight of unhusked ear (g)	199.94^{a}	173.36^{b}	186.99^{ab}
Length of husked ear (cm)	21.20^{ab}	22.00^{a}	20.53^{b}
Length of unhusked ear (cm)	17.26^{a}	17.00^{a}	16.80^{a}
Diameter of husked ear (cm)	51.56^{a}	51.02^{a}	52.55^{a}
Diameter of unhusked ear (cm)	44.76^{a}	44.01^{a}	44.56^{a}
Weight of husked ear plot^{-1} (kg)	5.67^{b}	6.27^{a}	6.45^{a}
Sweetness level (Brix)	12.60^{a}	11.46^{b}	12.93^{a}

* Duncan's multiple range test (P≤0.05) indicates that there is no significant difference between the means in the same row that are followed by the same letter.

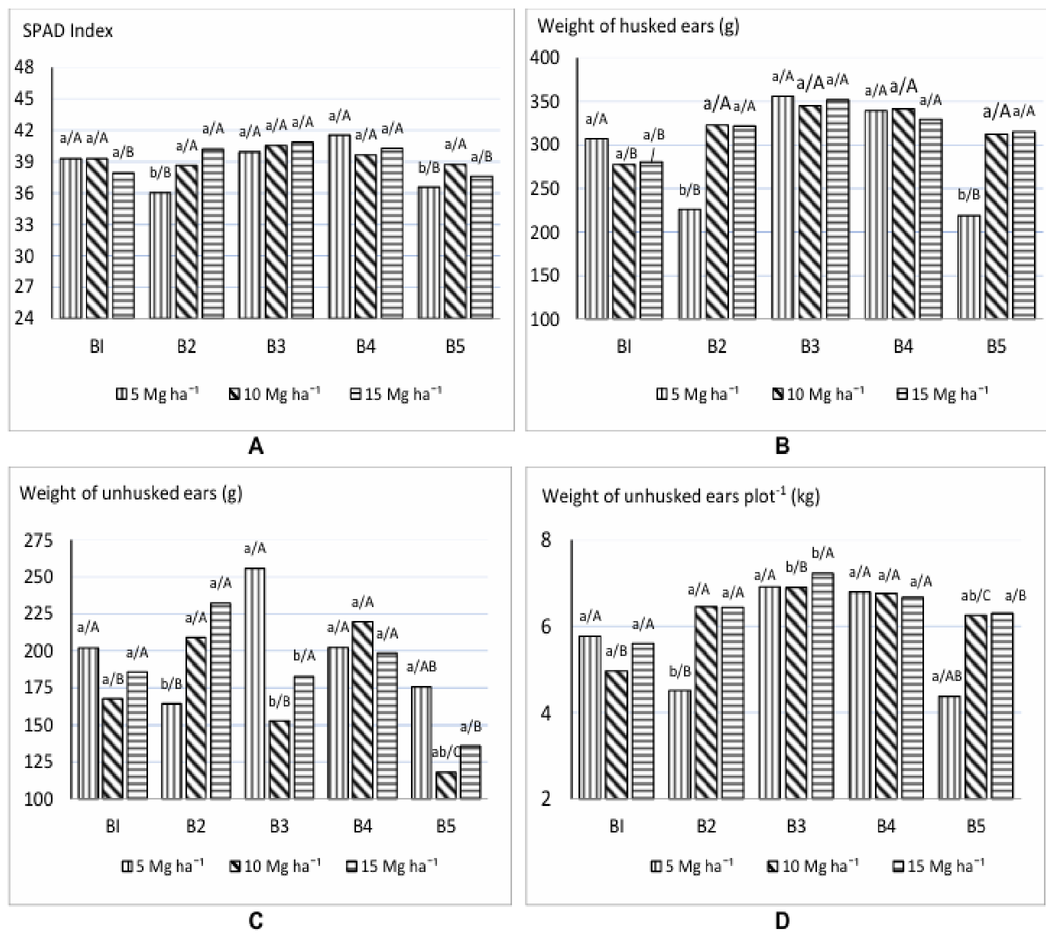

Figure 2. Effects of treatment interactions on leaf greenness (A), weight of husked ears (B), weight of unhusked ears (C) and weight of unhusked ears plot^{-1} (D). (Mean values followed by the lower and upper case letters are not significant difference among the bio activator type and dosage, respectively (Duncan's Multiple Range Test at P≤0.05. B1, B2. B3. B4, and B5, represent treatments of no bio-activator, cow blood, cow rumen+cow blood, yeast+cow blood, effective microorganism/EM4, respectively).

The treatment combination that produced the best weight of husked and unhusked sweet corn ears was also found in sweet corn fertilized with goat-manure based with 5 Mg ha^{-1} which was the cow rumen+cow blood bio-activator treatment. It is presumably that the optimal nutrient absorption and photosynthesis in sweet corn took place after fertilized with goat-manure that included the cow rumen+cow blood bio-activator at a dose of 5 Mg ha^{-1}. Susanti et al. (2023) suggested that the weight gain of sweet corn ears was correlated with both the rate of plant photosynthesis and the assimilation of translocation nutrients into the ears. The availability of nitrogen in sufficient quantities elevated the process of seed filling and ear enlargement. In our study, well-decomposed goat-based manure fertilizer, as indicated by its C/N ratio (6.20 to 8.45), improved the nutrient absorption, especially the potassium. Fahrurrozi et al. (2018) concluded that potassium is responsible for the increase of shoot dry-weight, weight of husked-ear and yield of sweet corn.

Although this study presents valuable insights into the use of bio-activators in goat manure fermentation and their effects on sweet corn performance, several technical limitations should be acknowledged. First, the experiment was conducted using a single sweet corn cultivar, which may limit the applicability of the findings to other genotypes with different growth responses or nutrient demands. In addition, the field trial was carried out over a single growing season and at one location, restricting the ability to generalize the results across varying climatic conditions, soil types, and agro-ecological zones. Moreover, the fermentation period (four weeks) may not fully reflect the dynamics of compost maturation or microbial stabilization due to the presence of xylanolytic bacteria in cow rumen or blood. This group of bacteria, which is considered as fast-growing and metabolically active in the early stages of organic matter decomposition, excessively consume nutrients from the decomposing organic materials and used them as energy sources, and eventually reducing the nutrient properties into levels below the Indonesian National Standard (SNI:19-7030-2004). Additionally, this research was deficient in analyzing soil microbial communities and did not evaluate the possible ecological consequences of applying bio-activators.

4. Conclusions

From the study, it can be concluded that goat manure-based fertilizer produced using cow rumen+cow blood bio-activators had the best nutrient content, which was 1.58% nitrogen, 0.17% phosphorus, 0.24% potassium, 16.7% magnesium, 9.46% organic carbon, C/N ratio of 6.2 and pH of 7.23. The presence of bio-activators (cow blood, cow rumen, yeast, and EM4) in goat manure-based fertilizer increased the weight husked ear, the weight of unhusked ear, the length of husked ear, the length of unhusked ear, and the weight of husked ear plot^{-1} of sweet corn, but not the diameter of husked ear, the diameter of unhusked ear, and the sweetness level of sweet corn. The use of goat manure-based fertilizer at 5 Mg ha^{-1} was generally sufficient to support sweet corn growth and yield. Finally, the goat-manure based fertilizer produced with the addition of the cow rumen+cow blood bio-activators at 5 Mg ha^{-1} in dosage was found to be the best treatment for boosting sweet corn growth and yield.

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6. Authors' Contributions

Isnin Kurnia Safitri: Data Curation, Formal Analysis, Investigation, Methodology, Writing-original draft; Fahrurrozi Fahrurrozi: Conceptualization, Funding Acquisition, Supervision, Writing- review & editing, Project Administration; Zainal Muktamar: Conceptualization, Funding Acquisition, Supervision, Writing- review & editing; Sigit Sudjatmiko: Formal Analysis, Supervision, Writing- review & editing.

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7. Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

8. AI Declaration

During the preparation of this work, the authors occasionally used Google Translate in order to ensure the proper English expressions. After utilizing this tool/service, the authors (Isnin Kurnia Safitri, Fahrurrozi Fahrurrozi, Zainal Muktamar, and Sigit Sudjatmiko) thoroughly paraphrased, reviewed and edited the content as necessary and take full responsibility for the final content of the published article.

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